Module 5 - Strain Applications

ME3023 - Measurements in Mechanical Systems

Mechanical Engineering

Tennessee Technological University

Topic 2 - The Bridge Factor

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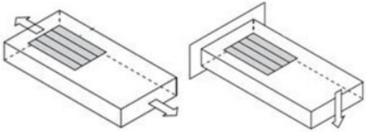
- The Quarter Bridge
- Using Multiple Gauges
- Apparent Strain and Temperature
- Example: Digital Scale

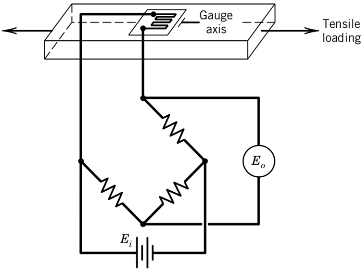
The Quarter Bridge

Hooke's law describes the linear relationship between stress and strain of an elastic member with modulus of elasticity E.

$\sigma = E\epsilon$

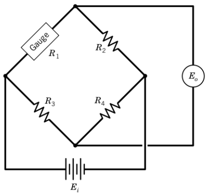
If the loading is known the beam models can be applied.





The Quarter Bridge

Consider the quarter bridge case in which the gauge is R_1 and $R_1 = R_2 = R_3 = R_4$ in a condition of zero strain.



$$E_{out} = E_{in} \times \left(\frac{R_1}{R_1+R_2} - \frac{R_3}{R_3+R_4} \right) \implies E_{out} = E_{in} \frac{(R_1 R_4 - R_2 R_3)}{(R_1+R_2)(R_3+R_4)}$$

Now, R_1 changes by δR causing E_{out} to change by δE_{out}.

$$E_{out} + \delta E_{out} = E_{in} \frac{((R_1+\delta R) R_4 - R_2 R_3)}{((R_1+\delta R)+R_2)(R_3+R_4)}$$

The Quarter Bridge

In practice the bridge is balanced in a condition of zero strain which gives an output voltage of $E_{out} = 0v$. Then any additional strain causes a δE_{out} which is measured.

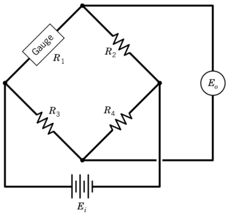
The previous equation is commonly written in the following practical form.

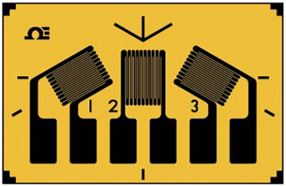
$$\frac{\delta E_{out}}{E_{in}} = \frac{\delta R/R}{4+2(\delta R/R)} \approx \frac{\delta R/R}{4} \quad \text{or} \quad \frac{\delta E_{out}}{E_{in}} = \frac{GF\epsilon}{4+2GF\epsilon} \approx \frac{\delta GF\epsilon}{4}$$

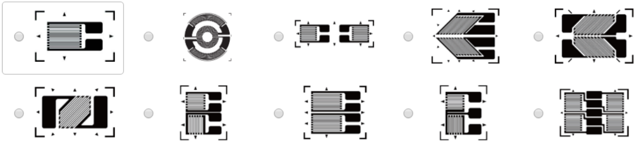
with Gage Factor defined as $GF \equiv \frac{\delta R/R}{\delta L/L} = \frac{\delta R/R}{\epsilon}$

Using Multiple Gauges

An improved system uses a set of gauges known as a rosette with the wheatstone bridge in a half or full bridge configuration.

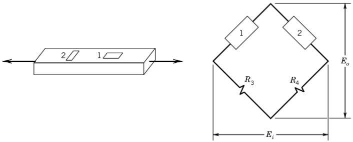






Using Multiple Gauges

If multiple gauges are used the relationship between strain and output voltage is derived with a similar process (see page 479).



The result gives an expression relating the output voltage, the gauge factor, and all four measured strains.

$$\frac{\delta E_{out}}{E_{in}} = \frac{GF}{4}\left(\epsilon_1 - \epsilon_2 + \epsilon_4 - \epsilon_3\right) = \kappa \frac{GF}{4}$$

The constant κ is known as the bridge factor.

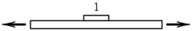
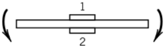
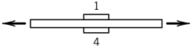
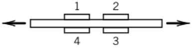
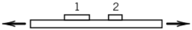
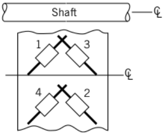
Apparent Strain and Temperature

Equation 11.22 shows that for a bridge containing one or more strain gauges, equal strains on opposite bridge arms sum, whereas equal strains on adjacent arms of the bridge cancel. These characteristics can be used to increase the output of the bridge, to provide temperature compensation, or to cancel unwanted components of strain.

Text: Theory and Design of Mechanical Measurements

This summarizes the reasons to use a wheatstone instead of a operational amplifier when measuring strain with a metallic strain gauge.

Apparent Strain and Temperature

	Arrangement	Compensation Provided	Bridge Constant κ
	Single gauge in uniaxial stress	None	κ = 1
	Two gauges sensing equal and opposite strain—typical bending arrangement	Temperature	κ = 2
	Two gauges in uniaxial stress	Bending only	κ = 2
	Four gauges with pairs sensing equal and opposite strains	Temperature and bending	κ=4
	One axial gauge and one Poisson gauge		κ= 1 +ν
	Four gauges with pairs sensing equal and opposite strains—sensitive to torsion only; typical shaft arrangement.	Temperature and axial	κ = 4

For more details read this document from NI.

Example: Digital Scale

Have you ever wondered how a digital scale works?

Does it matter where you place item? Why or why not?